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STEAM-TURBINE, GAS-TURBINE, AND COMBINED-CYCLE PLANTS AND THEIR AUXILIARY EQUIPMENT

# Experience Gained at the Ural Turbine Works with Retrofitting Steam Turbine Units for Thermal Power Stations

**A. E. Valamin[a], A. Yu. Kultyshev[a, b], A. A. Gol'dberg[a], T. L. Shibaev[a], and H. C. Paneque Aguilera[a]**

[a] *Ural Turbine Works, ul. Frontovykh Brigad 18, Yekaterinburg, 620017 Russia*

[b] *Ural Federal University, ul. Mira 19, Yekaterinburg, 620002 Russia*

**Abstract**—Examples of projects on retrofitting, modernizing, and renovating steam turbine units at thermal power stations implemented with participation of the Ural Turbine Works are given. Advanced construction and layout solutions were used in implementing these projects both on the territory of Russia and abroad.

*Keywords*: steam turbine unit, modernization, retrofitting, pedestal, layout, horizontal delivery-water heater, condenser, generator

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Recent years have seen ongoing modernization and replacement of existing equipment items by new more advanced ones in the electric power industry of Russia and CIS countries. This is primarily due to the fact that more than 60% of high-temperature thermal power equipment, such as boiler houses and steam turbine units (STUs) installed at cogeneration stations and district power stations (referred to henceforth as thermal power stations, TPSs) have worked out its service life.

Low tariffs for energy carriers and long periods of time for which investments in new construction are paid back are factors that compelled TPS owners, as well as the governments of Russia and other countries to take active efforts aimed at retrofitting the existing power stations.

Indeed, retrofitting or modernization is an option that makes it possible to obtain considerable saving of capital investments as compared with construction of new or expansion of existing TPSs. If we take the total costs for constructing a new cogeneration station or expanding an already existing one as 100%, then, according to the data of [1], the distribution of costs among the individual parts of such a project will be as follows: up to 40% for procurement of new equipment, up to 50% for civil construction works, up to 15% for erection works, and 2–3% for the other works.

Hence, by using the existing buildings, pedestals for equipment, crane facilities and replacing only obsolete equipment items by more advanced new ones, it is possible to safe around 40–50% of the total sum of money owing to exclusion of civil construction works alone taking into account some additional costs for dismantling the equipment that is subject to replacement.

Retrofitting and modernization are presently implemented in different ways: from partial replacement of assemblies the service life of which cannot be extended to full replacement of power unit equipment.

The Ural Turbine Works (UTZ) participates in activities concerned with modernizing, retrofitting, and renovating STUs produced by UTZ and by other manufacturers, on the territory of Russia and abroad. In our opinion, projects of retrofitting STUs in the existing turbine buildings of TPSs with retaining their dimensions and the majority of building structures, including the crane facility and with the maximally possible use of the existing turbine unit pedestal are the most interesting ones but requiring much effort for their development.

In this article, only a few TPS retrofitting projects developed with participation of the Ural Turbine Works are described.

The cogeneration station of the Ural Carriage Works was the first facility retrofitted with participation of UTZ [2]. The pedestal, which was constructed in the 1930s, supported an AT-25-2 two-cylinder turbine produced by the Leningrad Metal Works (LMZ) and a T2-25-2 generator produced by the Elektrosila Works. The actual state of the pedestal was examined, and it was recognized from the examination results that a new turbine set can be installed on this pedestal. After the overground structure of the pedestal in the turbine part and the upper plate in the generator part had been partially dismantled, and the dismantled components had been replaced by new ones, it became possible to install a new turbine set consisting of a PT-30/35-90/10-5 single-cylinder turbine produced by UTZ and a TFP-25-2U3 air-cooled generator pro-

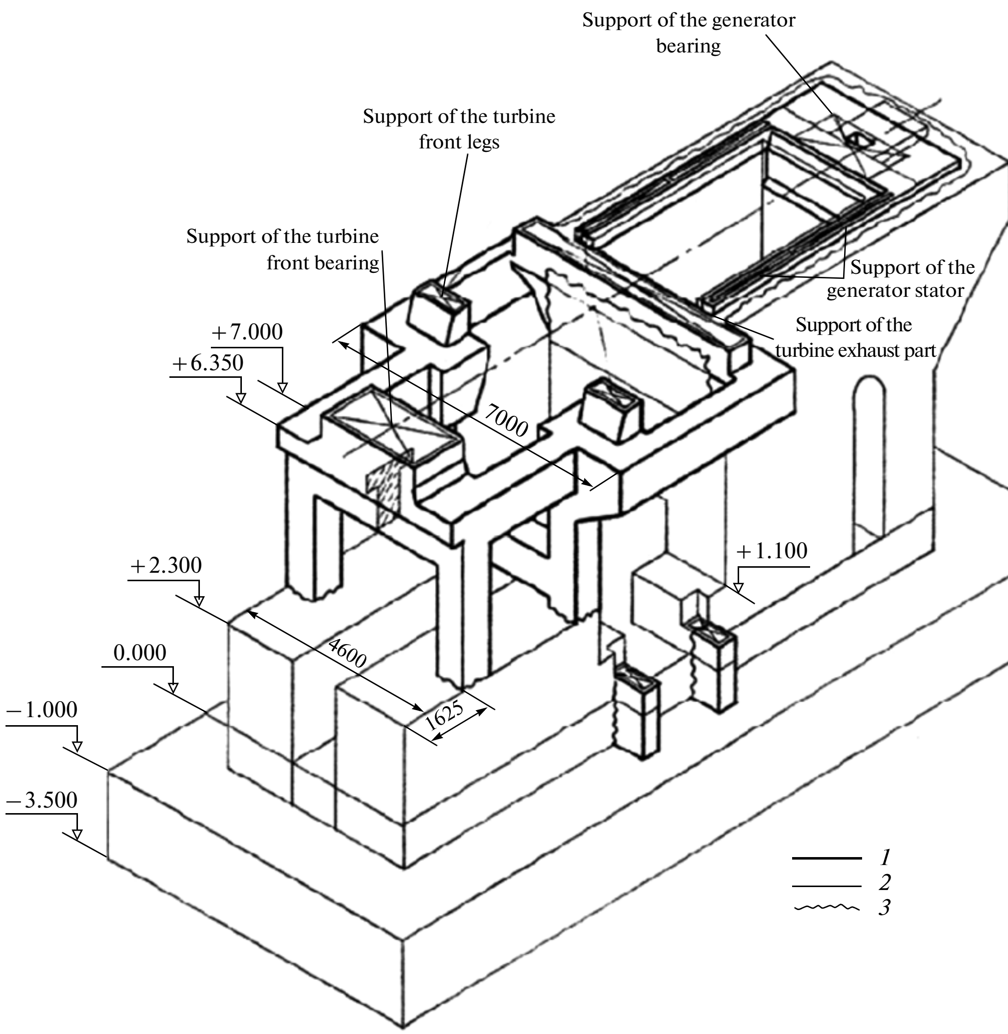



**Fig. 1.** Pedestal of the PT-30/35-90/10-5 steam turbine unit. (*1*) Overall dimensions of the new pedestal, (*2*) overall dimensions of the existing pedestal retained during the retrofitting, and (*3*) butt jointing of the new and existing pedestals.

duced by Elektrosila. The modified pedestal is shown in Fig. 1.

The remaining equipment was arranged within the confines of the old turbine building, with due regard of the four delivery-water heaters remained at their previous places, which had been replaced by new ones not long before the retrofitting.

In connection with possible inundation, limitations were imposed on the works in the floor of the condenser compartment, due to which design solutions were adopted that did not require making significant sumps or hydraulic locks in the floor. Retaining the elements of operating equipment and process lines adjacent to the new turbine unit was also a challenging task.

The cogeneration station of the Siberian Chemical Combine in the city of Seversk, in which the entire thermal power equipment installed in the turbine building had to be retrofitted, was one of the most difficult facilities for UTZ. The new Tp-100/110-90 turbine was installed instead of the VKT-100-90 turbine (produced by the Kharkov Turbine Works), which had worked out its service life, and the old generator had to be replaced by a TF-110-2UZ air-cooled generator produced by NPO ELSIB. The new (also two-cylinder) Tp-100/110-90 turbine unit with one exhaust hood and one condenser differed essentially in its design from the dismantled turbine unit, which had a low-pressure cylinder (LPC) with two exhaust hoods and two condensers.

Very tight constraints were imposed on the STU civil construction part in that project: the turbine unit pedestal—a reinforced-concrete wall structure with extremely tight conditions inside the foundation—had to be retained almost completely (Fig. 2). According to the contract, the new STU was fitted with two PSG-2200 horizontal delivery-water heaters (HDWHs) designed for an increased pressure of network water. To mini-

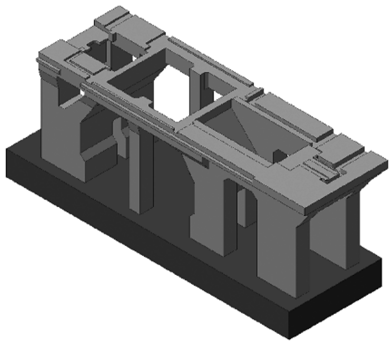


**Fig. 2.** Pedestal of the Tp-100/110-90 steam turbine unit.

mize the amount of civil construction works and to maximally retain the pedestal, its retrofitting was reduced to modifying only those elements that could not be retained in their initial form. For example, in installing the HDWH No. 2 under the generator inside the foundation, some amounts of concrete were cut away in the pedestal walls with leaving the minimal gap between the concrete and equipment. The HDWH No. 1 was installed into the pedestal opening in which one of the condensers was located previously. The pedestal's upper structure was modified only in the part of installing new pedestal frames and in making new wells for anchor studs. Figure 3 shows how the HDWHs are arranged within the pedestal overall dimensions. In addition, the crossover pipes of the high- and intermediate-pressure cylinders (HPC and IPC) and the steam extractions to the high- and low-pressure heaters were routed so as to simultaneously fulfill the requirements for self-compensation, strength, convenience of erection, and maximal retaining of the pedestal structure.

The Perm TETs-14 cogeneration station was a facility the retrofitting of which involved difficulties in implementing layout and civil construction solutions. According to the project, it was necessary to install a T-35/55-1.6 bottom steam turbine [3] operating on steam supplied from the process header. It should be noted that the R-100-12.8 turbine, which had been taken out from operation for a long period of time due to the lack of steam consumers, also began to operate on this header after the retrofitting. As a result, the station power output increased by 135 MW. The new T-35/55-1.6 turbine was installed on the place of the T-50-90-2 turbine, which had worked out its service life.

As in the previous example, retaining of the turbine unit pedestal to the maximum possible extent was the most challenging requirement in designing the STU. In addition, the customer requested to leave the existing generator on its original place even in the course of retrofitting and to use it afterwards with the new turbine. Thus, UTZ specialists had to develop an STU project with a bottom turbine with due regard of the above-mentioned requirements.

Since the new turbine was installed on the existing pedestal of the two-cylinder turbine, the main difficulties were encountered in modifying the pedestal's overground structure. The pedestal's part under the generator had to be retained fully intact because the generator had to remain on its original place. The scope of supply included, along with a T-35/55-1.6 turbine, a PSG-1300 horizontal delivery-water heater. A few versions of arranging the PSG-1300 apparatus were elaborated, after which it was decided to install it on the pedestal before the turbine. The use of such version made it possible to bring the load applied to the turbine unit pedestal lower plate to its design level. As a result, the lower plate, the pedestal's generator part, and the columns in the pedestal's turbine part were fully retained. A new pedestal upper plate directly connected with the foundation frames of the new turbine was made in the turbine part. Figure 4 shows the general view of the turbine unit pedestal, and Fig. 5 shows the STU layout.

As was already mentioned, a customer whose STU is to be retrofitted wishes to use the pedestal of the replaced turbine unit or only the turbine pedestal to

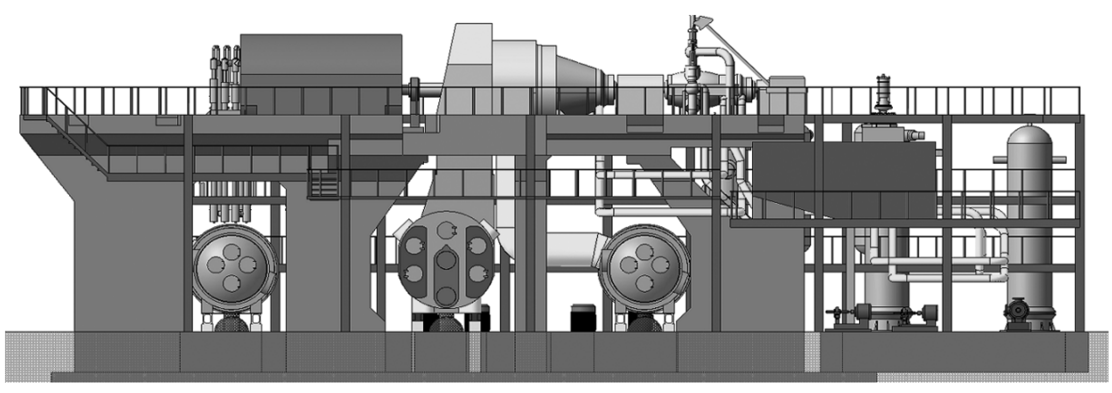


**Fig. 3.** Layout of the Tp-100/110-90 steam turbine unit.

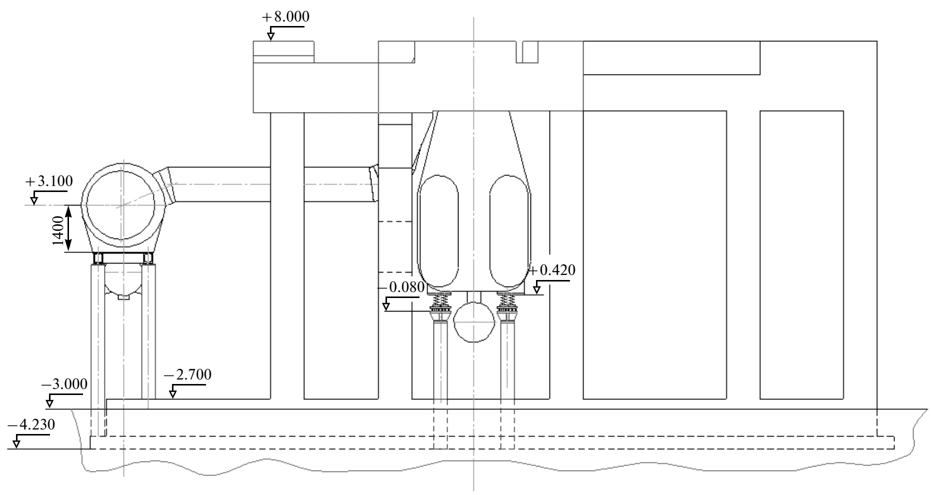



**Fig. 4.** Pedestal of the T-35/55-1.6 turbine unit.

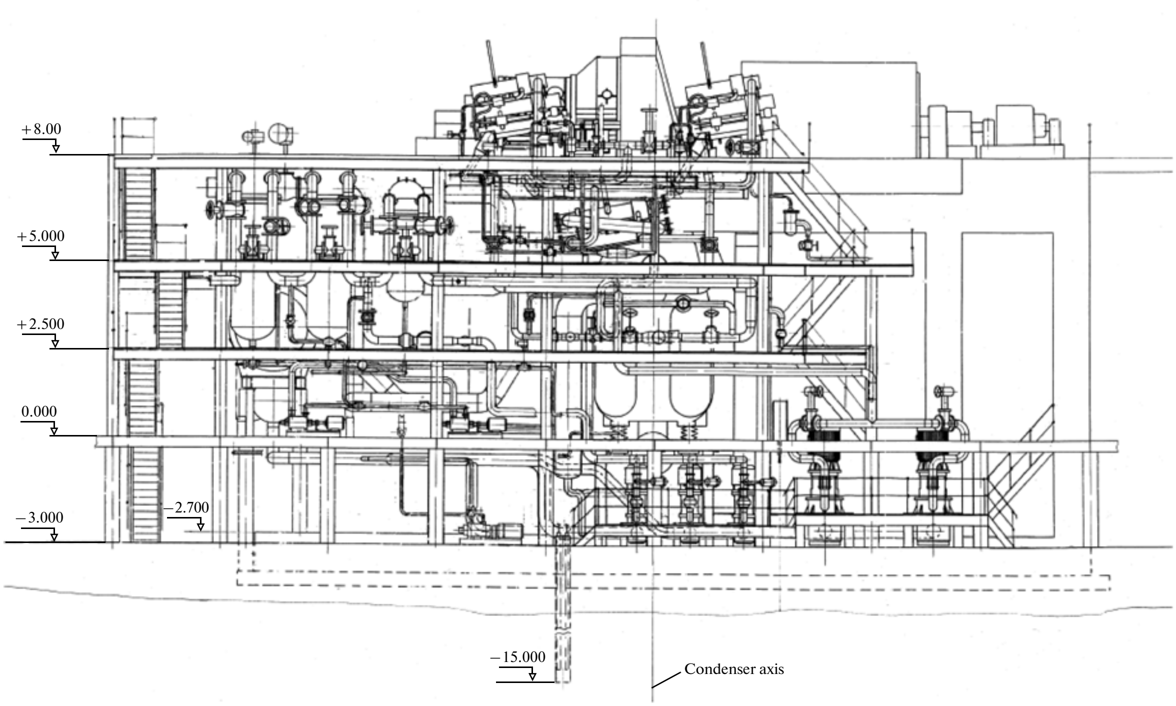



**Fig. 5.** Layout of the T-35/55-1.6 turbine unit.

install the new equipment on it. Of course, such a pedestal must comply with all requirements for its further operation. However, there is often nothing to do but dismantle the entire or almost the entire overground part of the pedestal, leaving and using only its lower plate.

UTZ specialists had to follow this path in working out the STU retrofitting project for the Ulan-Ude TETs-1, Pavlodar TETs-3 (Kazakhstan), Petropavlovsk TETs-2 (Kazakhstan), and Vladimir TETs-2 cogeneration stations.

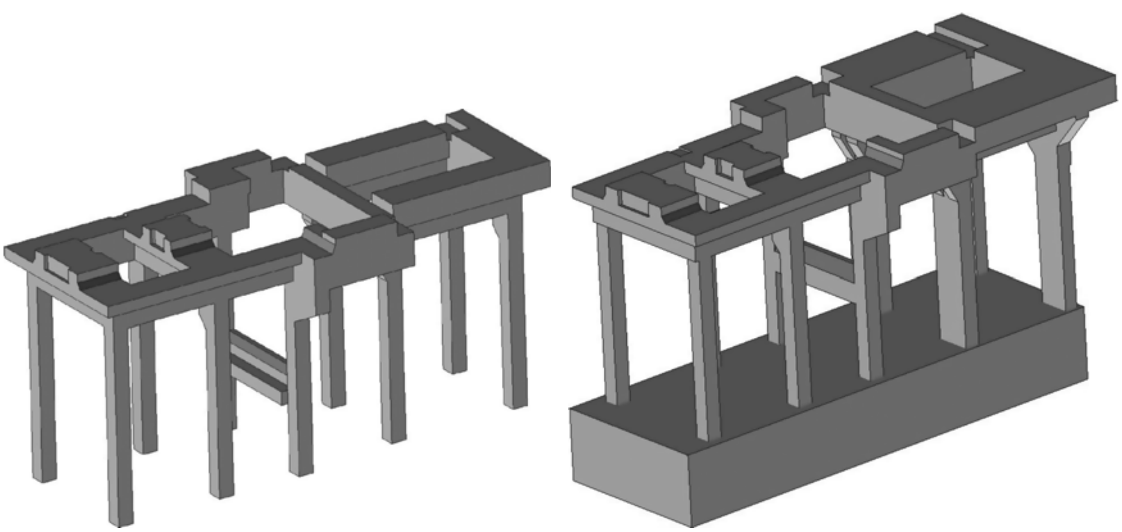
A Tp-100/110-8.8 cogeneration STU produced by UTZ with a heating extraction to the station header and connected to a TF-110-2U3 air-cooled generator produced by NPO ELSIB was arranged at the Ulan-Ude TETs-1 cogeneration station in its turbine build-

**Fig. 6.** External view of the existing lower plate.

ing on the place of the fire-damaged VK-100-6 STU connected to a TVF-100-2 hydrogen-cooled generator.

Examinations and geological surveys were carried out, after which the customer decided that only the turbine unit pedestal's lower plate and the reinforced-concrete piers in the cellar compartment (with partially replacing the floor slabs of the condenser compartment) had to be retained of the existing building structures. Workers of a dedicated organization cut the pedestal columns almost flush with the upper surface of the pedestal lower plate with the use of special technology. The external view of the reinforced-concrete structure remained after this operation is shown in Fig. 6. Requirement specifications were developed at UTZ for the pedestal and floors with the use of the foundation lower plate and the structures that remained in the turbine building. The columns and the pedestal upper structure were made in accordance with the configuration required for installing the Tp-100/110-8.8 turbine and the TF-110-2U3 generator. The pedestal design is shown in Fig. 7a. Not only did the cogeneration station's power output reach its pre-accident level as a result of the accomplished retrofitting, but it even exceeded its original capacity, and the station received a modern STU.

In connection with the fact that the PT-60 turbine (produced at the Czech Republic) installed at the Pavlodar TETs-3 cogeneration station had become physically worn, UTZ supplied a PT-65/75-12.8/1.3/13 cogeneration steam turbine with process and heating extractions to the station headers and with a new TF-63-2U3 generator. As at the Ulan-Ude TETs-1 cogeneration station, the pedestal upper structure and part of columns to the floor level in the condenser compartment were dismantled at the Pavlodar TETs-3 cogeneration station. However, in contrast to the previous project, the pedestal lower plate was strengthened by 500 mm in height. Elaborations of the pedestal lower plate were carried out in order to retain the central cable channel, which housed electrical cables, because it was not possible not only to shift, but even to disconnect them during the retrofitting. Apart from the pedestal lower plate, the electrically driven feedwater pumps and the station boiler unit were retained on their places. This circumstance added difficulty to the work on developing the STU layout, but made it possible to save a considerable sum of money in retrofitting the cogeneration station turbine building. The drawing of the turbine unit pedestal is shown in Fig. 7b, and the STU layout is shown in Fig. 8.



(a) (b)

**Fig. 7.** Pedestals of the Tp-100/110-8.8 steam turbine unit installed at the TETs-1 cogeneration station in the Ulan-Ude city (a) and of the PT-65/75-130/13 steam turbine unit (b).

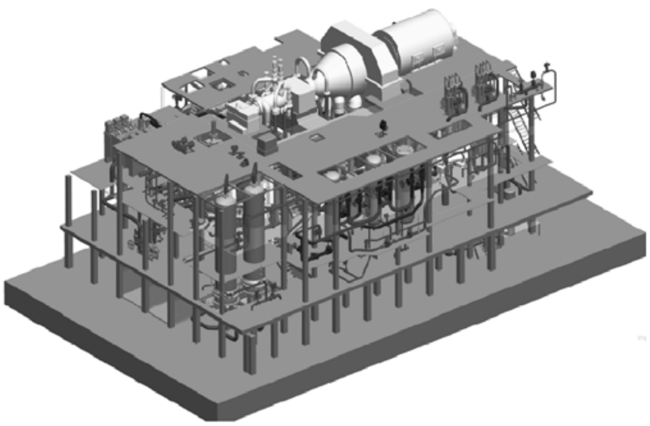


**Fig. 8.** Layout of the PT-65/75-130/13 steam turbine unit.

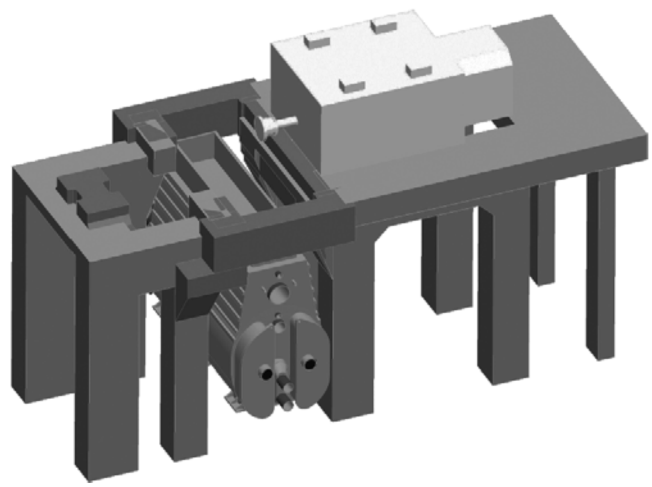


**Fig. 9.** Adapting the pedestal of the VK-50 turbine for the K-63-8.8 turbine.

The list of products manufactured by the Ural Turbine Works includes, among other items, a T-50/60-8.8 cogeneration steam turbine and a K-63-8.8 turbine developed on its basis, which can be used for replacing the widely used VT-50 and VK-50 turbines designed by the Leningrad Metal Works (LMZ). The LMZ turbines have a wall-type pedestal, and it should be noted that the generator and turbine parts have no connections in the pedestal overground structure. This circumstance led to the need of searching for the optimal technical solution in working out the scheme of arranging the turbine and generator on the pedestal. Two turbine placement versions were elaborated. According to the first version, the pedestal structures under the generator and turbine have no braces between them. In the second version, it was supposed to make such brace at the level of the pedestal upper plate. Both the versions were reviewed by the VIBRAM Company from St. Petersburg, which is the principal designer of the working projects of pedestals for UTZ turbines. As a result of that consideration, the second version of the pedestal overground structures was adopted. Thus, the retrofitting of the pedestal overground structure consisted of making longitudinal girders and structural elements in the upper plate for the turbine unit foundation frames. The general view of the modified pedestal is shown in Fig. 9. In the course of retrofitting the Petropavlovsk TETs-2 cogeneration station in Kazakhstan, a new K-63-8.8 turbine must be installed on such pedestal with retaining the existing TV-60-2 generator.

Retrofitting of the STUs installed at thermal power stations carried out with retaining a considerable part of the turbine building civil structures makes it possible to achieve essential reduction of capital outlays and to put new capacities in operation within shorter periods of time. However, there is a number of conditions that determine the possibility and confines of implementing STU retrofitting projects. The list of such conditions includes the following ones:

**The composition of equipment used in the dismantled and newly erected STUs.** Certain difficulties are encountered, e.g., in designing the layout of a cogeneration STU with an HDWH installed instead of a purely condensing STU. These difficulties are mainly stemming from the need to find the place for installing the HDWH if it is not possible to arrange it within the pedestal confines. A different number of steam turbine cylinders may also be a limiting factor both when a turbine with a fewer number of cylinders is replaced by a turbine with a larger number of cylinders and vice versa. For example, when a two-cylinder turbine is replaced by a single-cylinder one, difficulties arise with ensuring uniform distribution of the loads exerted on the pedestal lower plate.

**The state of the existing turbine unit pedestal.** In some cases, inundation of concrete, its impregnation with oil, deterioration, and other factors make further use of the pedestal impossible. Such factors should be revealed at early stages, as a rule, well before to commence the design works on retrofitting an STU. Dedicated examination must determine the state of bearing structures and the possibility of using individual elements or the pedestal as a whole.

**Height elevations of the floors in the turbine and condenser compartments.** The height size between the first and second height elevations must be larger that the height of the new condensers together with the hot well and the part of the turbine exhaust hood. It is preferable to retain the turbine compartment floor elevation adopted at the station. The floor of the condenser compartment must also coincide with that existing at the station.

**The existing crane facilities** should be considered in different aspects. First, the bridge crane lifting capacity must be sufficient for using it in the course of erection works and during operation for lifting the heaviest components of the new STU, such as the low-pressure cylinder's (LPC) upper half and the casing of the high-pressure heater (HPH). The stator of the new generator can be installed, if necessary, using a dedicated technology. Second, the crane hook lifting height above the turbine compartment floor must be sufficient for lifting bulky elements of the new STU (the LPC upper half and the HPH casing) and moving them over the turbine hall during operation.

**Performance of earth moving works** in the turbine buildings of some stations is impossible or difficult due to a number of factors, for example, due to the fact that the hydraulic locks and sumps are made below the floor height elevations of the condenser compartment or cellar. Each case of such sort for a particular facility must be addressed individually.

It can be seen from the examples presented above that the layout and civil construction solutions adopted in retrofitting or modernizing STUs at thermal power stations are strictly individual rather than typical in nature.

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